

Reduction of Launch Mass with Solar Sail Propulsion

Mars Sample Return Concept Study

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DEPLOYTECH Background

- ◆ Three year project awarded to Surrey Space Center by the European Commission
- ◆ Three main objectives for the DEPLOYTECH Project
 - ◆ Advance technology readiness levels of space deployable technologies
 - ◆ Develop updated mathematical models to analyze deployable structures
 - ◆ Develop testing methods and facilities for ground based tests of space deployable structures
- ◆ Partnership between NASA MSFC and University of Surrey to aid in development of space deployable technologies
 - ◆ Principal Investigators: Les Johnson and Vaios Lappas
 - ◆ NASA MSFC Engineering Directorate Support



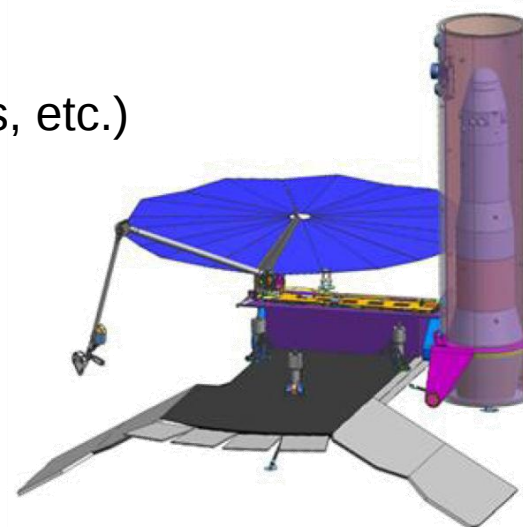
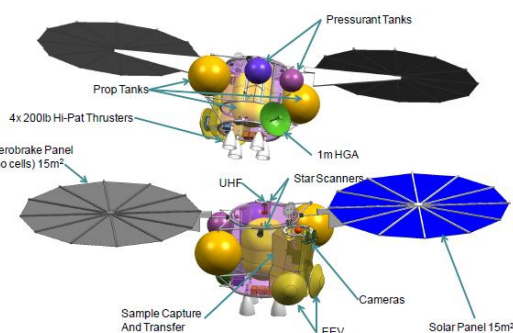
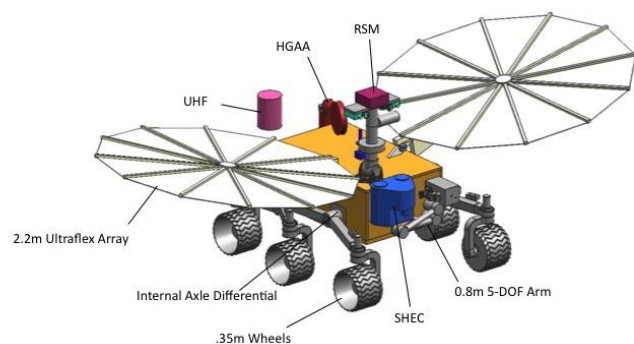
Mission Overview

◆ Planetary Science Decadal Survey Mission

- ◆ Three 'separate' missions to remain under cost caps
 - Astrobiology Explorer (Rover)
 - Sample Return Orbiter (with EEV)
 - Sample Return Lander (with Ascent Stage)

◆ MSR ERS Modifications

- ◆ Replace Sample Return Orbiter MPS system with solar sail
 - Maintain EEV from Decadal Survey Mission
 - Determine solar sail characteristics (size, mass, etc.)
 - Determine new spacecraft characteristics (size, mass, etc.)





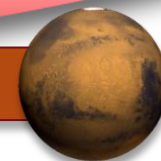
Mission Concept Assumptions

- ◆ Repackage the Sample Return Orbiter to minimize mass and redundancy
- ◆ Launch with Max-C rover on Atlas V 551 in 2028
- ◆ Use solar sail as main interplanetary propulsion system
 - ◆ Case 1 – Mars-to-Earth transfer only
 - ◆ Case 2 – Earth-to-Mars and Mars-to-Earth
- ◆ Limited RCS for course correction and sample rendezvous procedures
- ◆ Orbiter and ERS separate at Mars, ERS only returns to Earth with sample



Case 1: Mars-to-Earth Only

Mars



Mars Orbit

*Aerocapture into
Mars Orbit*

Rendezvous
w/ Orbiting Sample

Sample
Return
Orbiter
Operations

Orbiter
and ERS
Separation

Solar Sail
Deployment

*Orbiter
Expendable*

*Mars Spiral Out
~435 days*

*Mars-to-Earth Transfer
~507.5 days*

*EEV
Separation*

*Earth Entry
Velocity
< 12 km/sec*

*Direct
Entry*

*Mars Transfer
~350 days*

TMI

TMI Stage
Expendable

LEO

Total Transit Time = 3.54 years

Earth

Not to scale

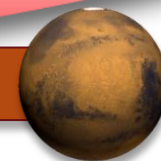
Expendable Launch Vehicle





Case 2 : Round Trip

Mars



Mars Orbit

Mars Arrival

Rendezvous
w/ Orbiting Sample

Sample
Return
Orbiter
Operations

Orbiter
and ERS
Separation

Mars Spiral Out
~435 days

*Orbiter
Expendable*

Mars Transfer
~758.5 days

Solar Sail
Deployment

TMI

TMI Stage
Expendable

Mars-to-Earth Transfer
~507.5 days

*EEV
Separation*

*Earth Entry
Velocity
< 12 km/sec*

*Direct
Entry*

Total Transit Time = 4.66 years

Earth

Not to scale

Expendable Launch Vehicle





Case 1: Mars Spiral Out

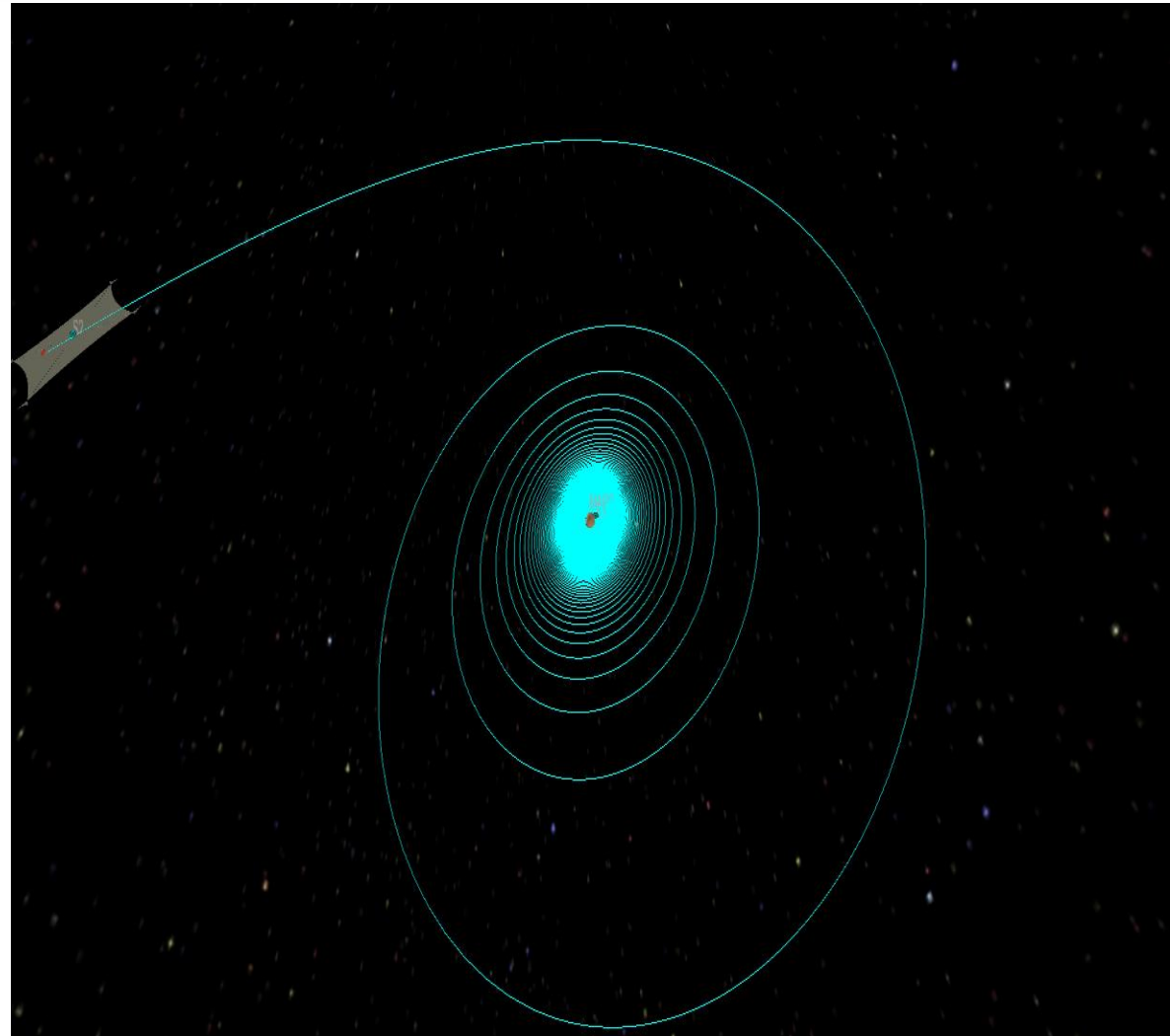
◆ Assumptions

- ◆ Area = 18,887 m²
- ◆ Payload Mass = 200 kg
- ◆ Sail Mass = 115 kg
- ◆ 2.5 μ m CP1
- ◆ Sun Synchronous Orbit
- ◆ Start at 500 km Circular orbit
- ◆ 93.2 inclination

◆ Characteristic

Acceleration = 0.50
mm/s²

◆ Time of Flight is 435
days

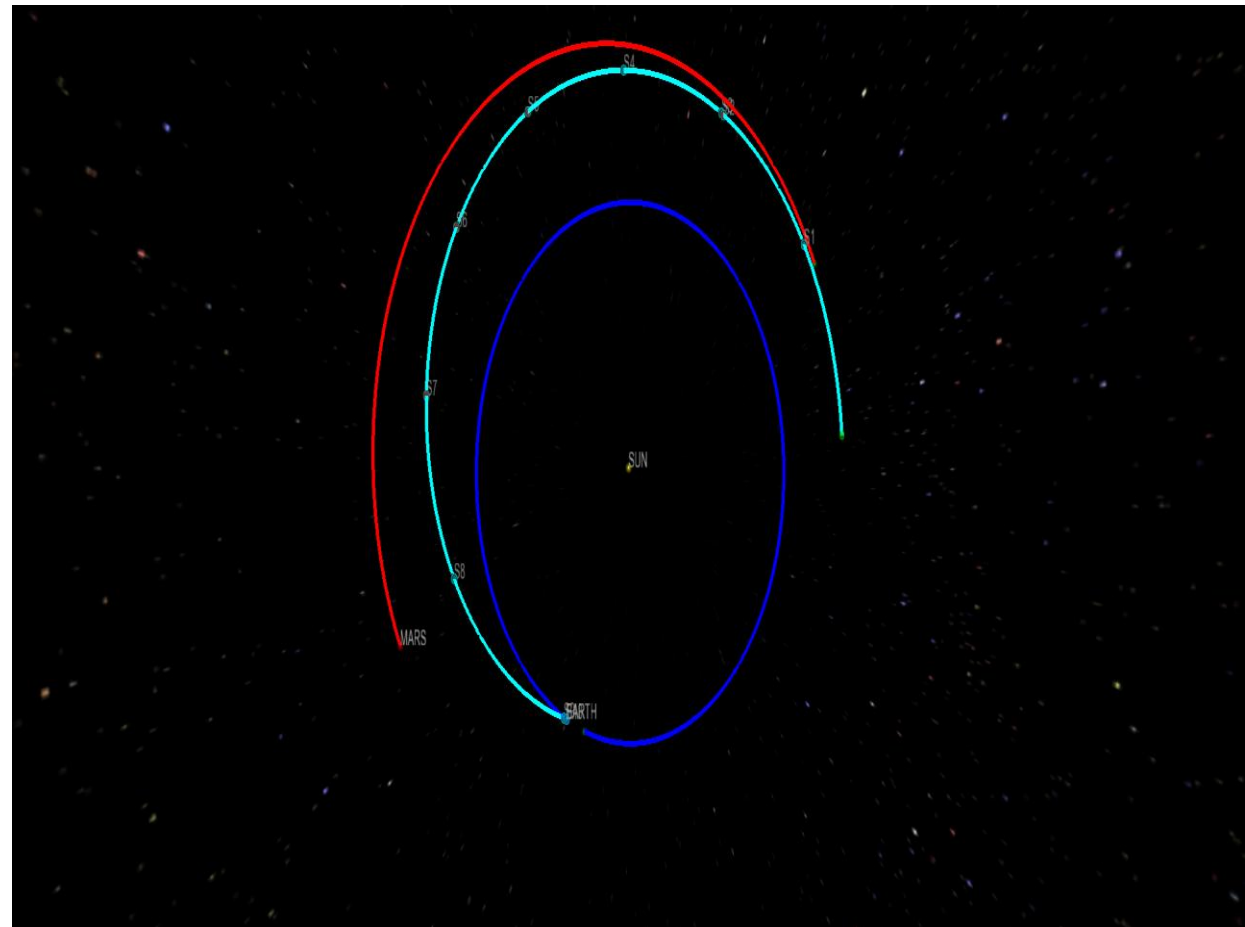




Case 1 & 2: Mars-to-Earth Transfer

◆ Assumptions

- ◆ Leaving Mars at perihelion
- ◆ Initial orbit Mars orbit
- ◆ V_{inf} of arrival of 6.4 km/s
- ◆ Entry velocity of 12.8 km/s
- ◆ Time of Flight is 507.5 days





Case 2: Earth-to-Mars Transfer

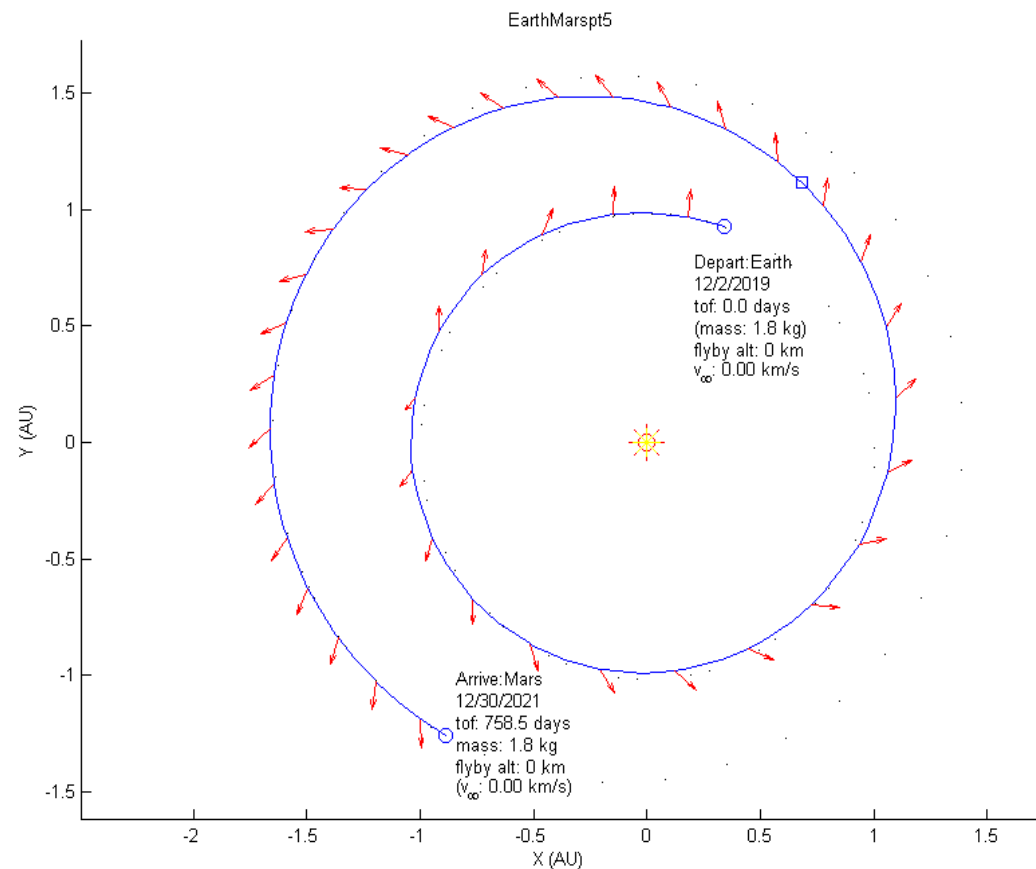
◆ Assumptions

- ◆ Leaving Earth with a C3 of zero
- ◆ Sail deployed after TMI burn by launch vehicle

◆ Characteristic

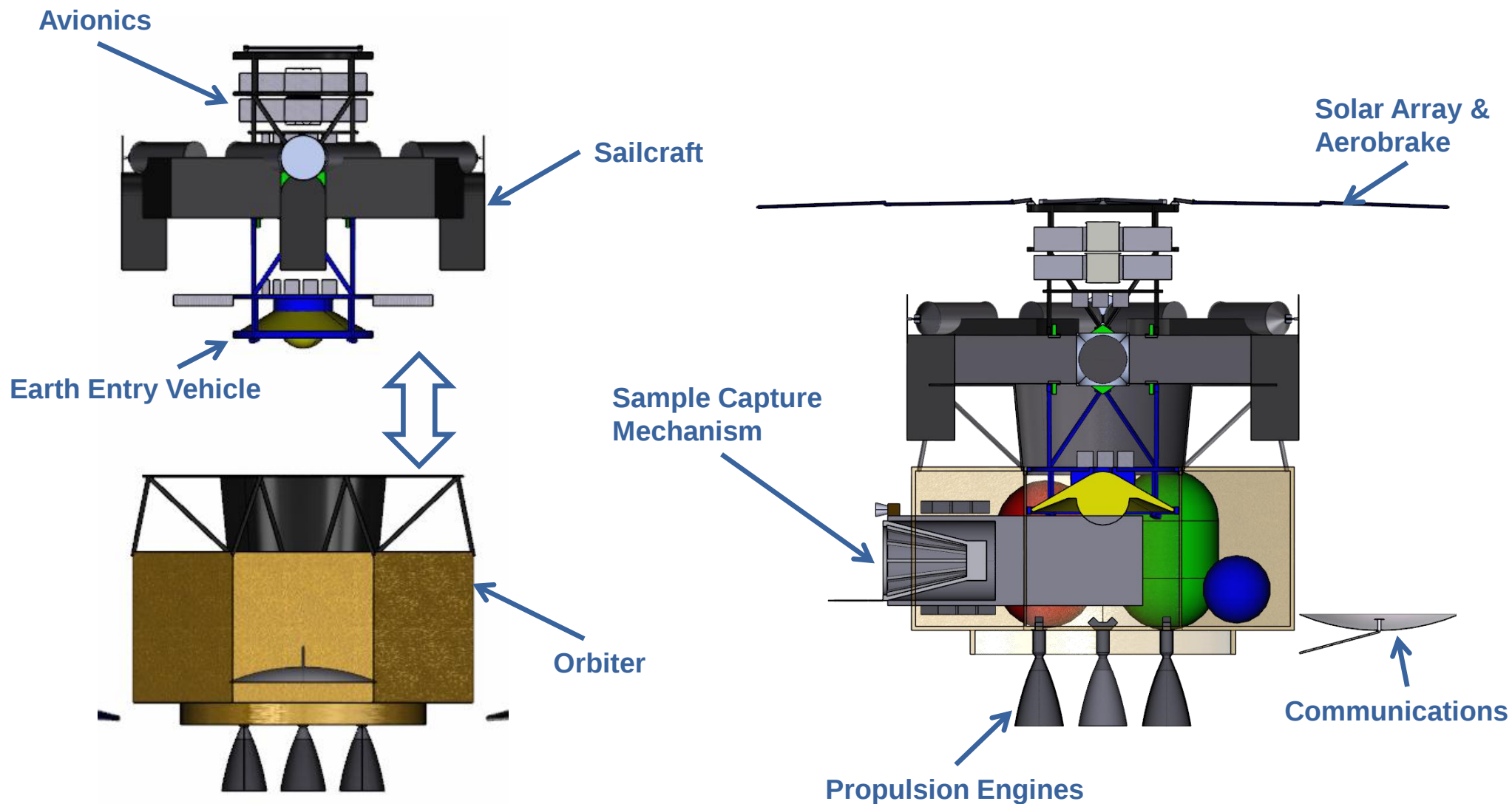
Acceleration = 0.50 mm/s^2

◆ Time of Flight is 758.5 days



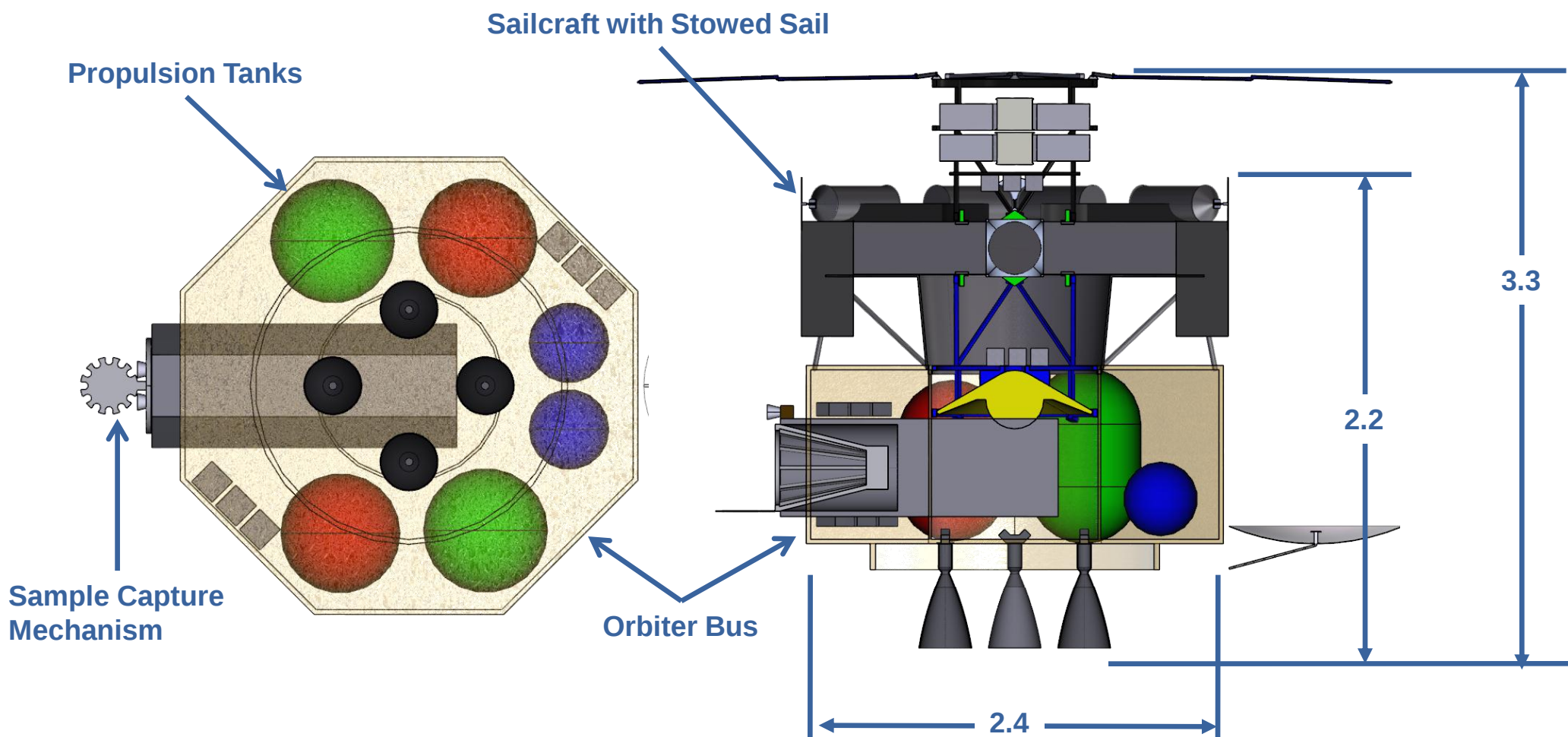


Configuration





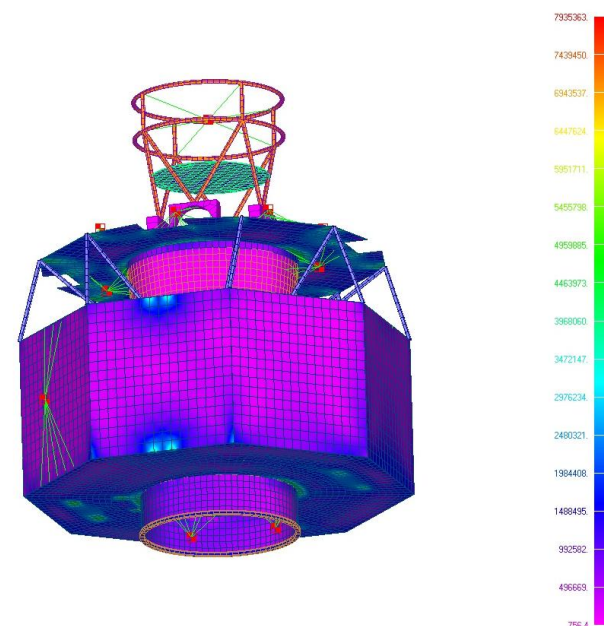
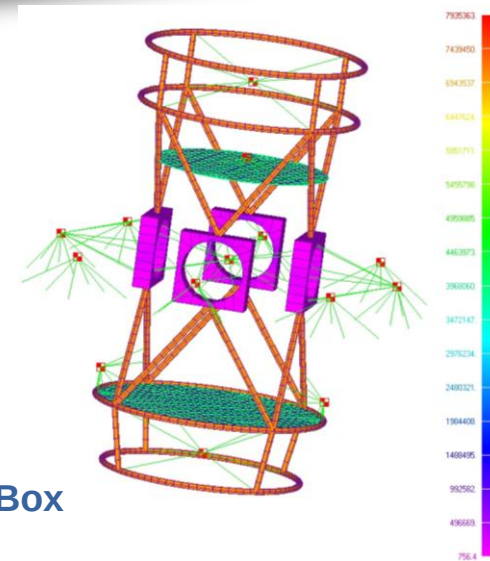
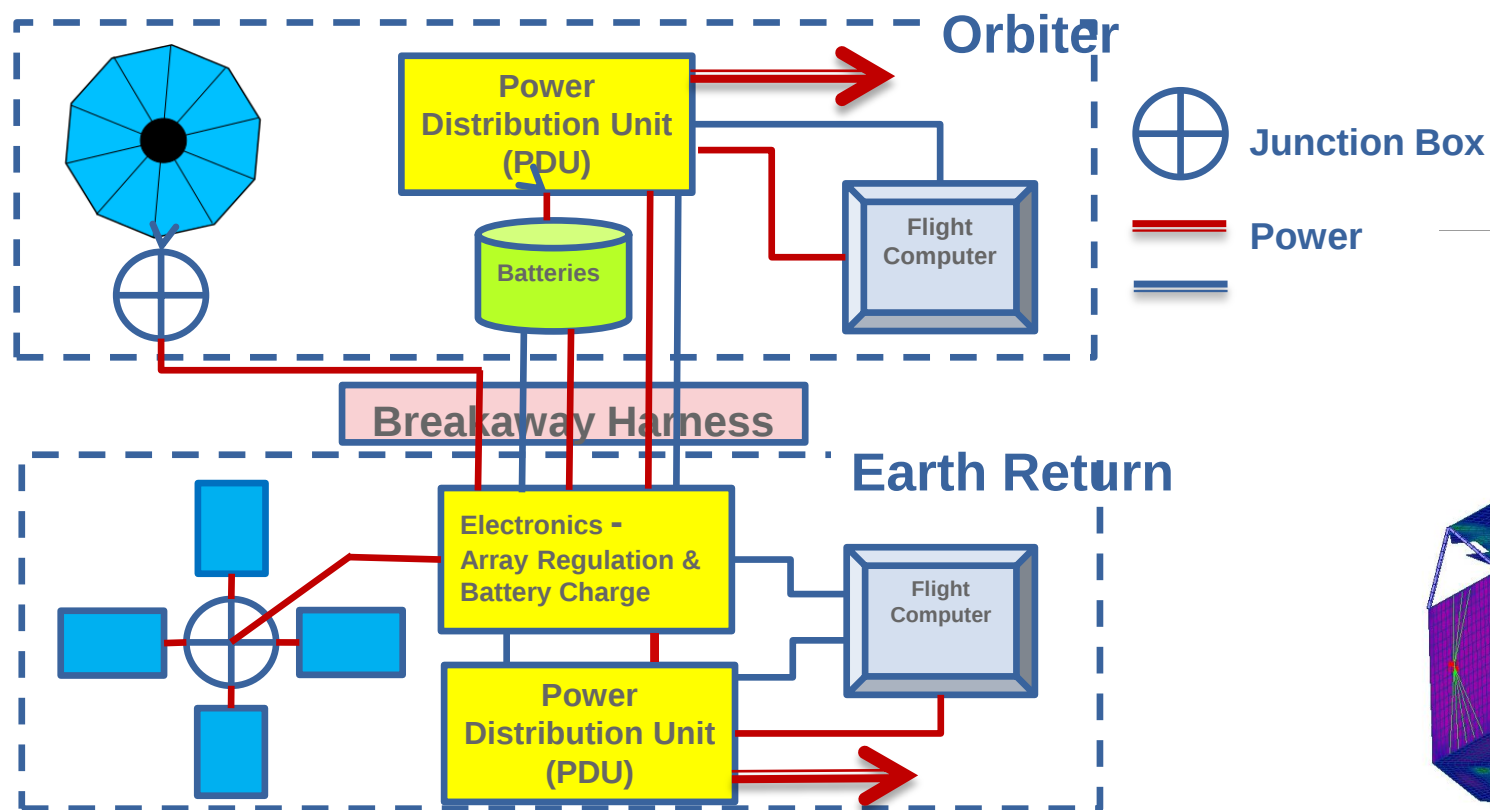
Configuration





Systems Analysis

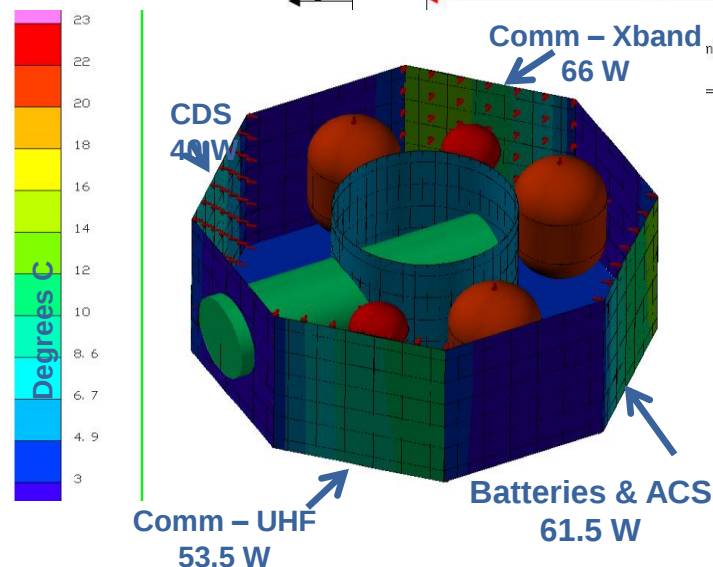
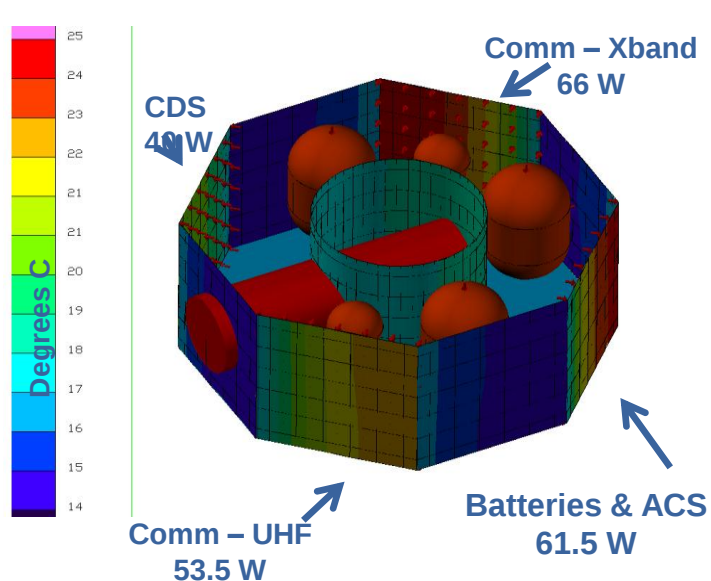
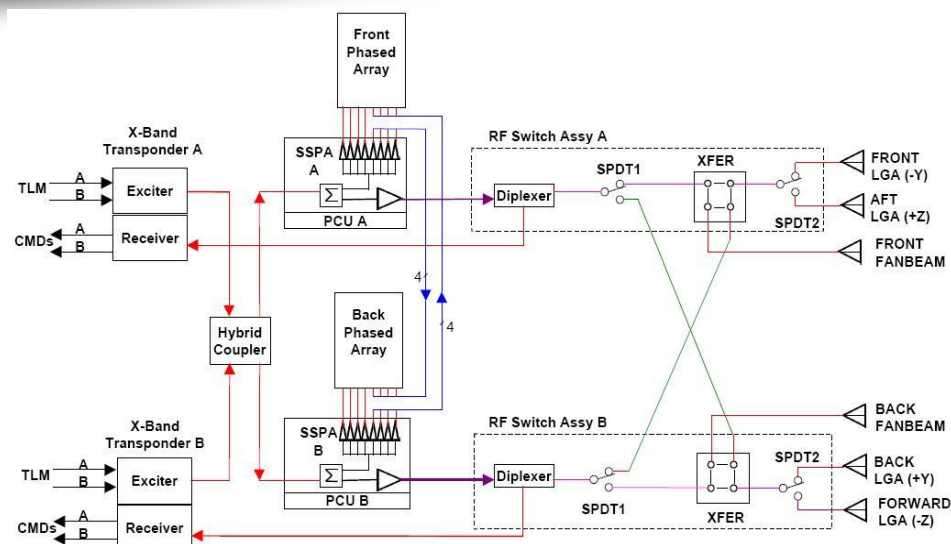
- ◆ Structures: Finite Element Analysis
- ◆ Power: Power Distribution Schematic





Subsystems Analysis

- ◆ Avionics: C&DH Schematic
- ◆ Thermal Analysis



Phased arrays are linear polarization.
All other antennas are right-hand circular polarization.



Mass Results

Case 1	Predicted Mass (kg)
Max-C Entry System	1550.7
Descent Stage	1313.1
Pallet	327.5
Max-C Rover	364.5
ACO Orb+ERS	1947.5
Total	5503.3

Case 2	Predicted Mass (kg)
Max-C Entry System	1550.7
Descent Stage	1313.1
Pallet	327.5
Max-C Rover	364.5
ACO Delta Orb+ERS	508.8
Total	4064.6

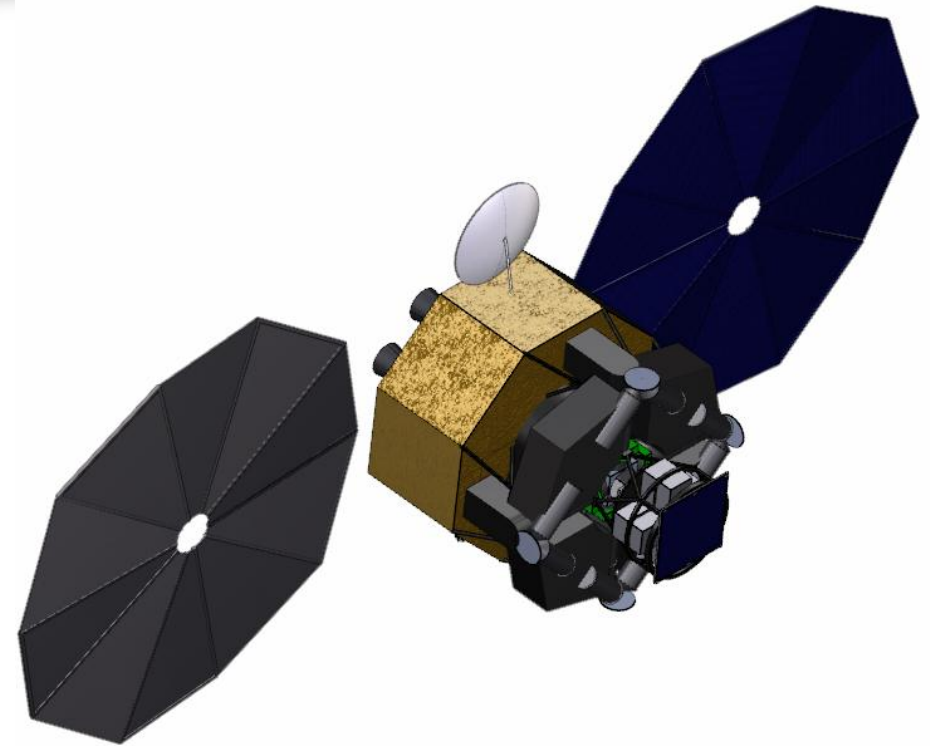
Launch Summary	
2028 Atlas V 551 Mass (kg)	5150
Delta Mass (kg)	4064.6

Launch Contingency: 21%



Conclusions

- ◆ Presented to the Mars Project for consideration
- ◆ Dual launch manifest enabled if a solar sail is utilized on a round trip
- ◆ Repackaged the Orbiter and Earth Return System into a configuration that allows stowage and deployment of the 150 M solar sail system



Met all mission requirements and would eliminate one Atlas V launch saving the project time and money!

